

DECOMMISSIONING EXPERIENCE FROM THE  
EXPERIMENTAL BREEDER REACTOR-II

by

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# **Decommissioning Experience from the Experimental Breeder Reactor-II**

## Introduction

Consistent with the intent of this International Atomic Energy Agency technical meeting, decommissioning operating experience and contributions to the preparation for the Coordinated Research Project from Experimental Breeder Reactor-II activities will be discussed. This paper will review aspects of the decommissioning activities of the Experimental Breeder Reactor-II, make recommendations for future decommissioning activities and reactor system designs and discuss relevant areas of potential research and development.

## EBR-II Operating Summary

The Experimental Breeder Reactor-II (EBR-II) was designed as a 62.5 MWt, metal fueled, pool reactor with a conventional 19 MWe power plant. The productive life of the EBR-II began with first operations in 1964. Demonstration of the fast reactor fuel cycle, serving as an irradiation facility, demonstration of fast reactor passive safety and lastly, was well on its way to close the fast breeder fuel cycle for the second time when the Integral Fast Reactor program was prematurely ended in October 1994 with the shutdown of the EBR-II.

The shutdown of the EBR-II was dictated without an associated planning phase that would have provided a smooth transition to shutdown. Argonne National Laboratory and the U.S. Department of Energy arrived at a logical plan and sequence for closure activities. The decommissioning activities as described herein fall into in three distinct phases.

## Current Status

The plan describing the final condition of the EBR-II, was implemented in October 2000. By this time many important steps had been performed, forming the basis for the plan. Specifically, defueling of the reactor, the design and construction of the sodium process facility and initial sodium processing had taken place.

At the writing of this paper, all physical work associated with the decommissioning activities of the EBR-II are complete. Remaining activities are limited to completion of final documentation specifying actions taken on a system-by-system basis, providing the final configuration control. The following activities have been completed:

- Reactor defueling,
- Spent fuel placed in interim storage,
- Sodium Process Facility made operational,
- Primary and secondary sodium coolant removed from reactor systems,
- Sodium potassium coolants processed with sodium,
- Sodium coolant converted to solid sodium hydroxide for disposal,
- Passivation of sodium remaining within secondary and primary systems, and
- Reactor and non-reactor systems placed in a radiological and industrially safe condition.

## Phase I EBR-II Decommissioning Activities

The initial phase of decommissioning activities was reactor defueling, completed in December 1996. Defueling was initiated in October 1994 and was completed 14 months later, 3 months ahead of schedule. Defueling included:

- Removal of 637 assemblies from the reactor core,
- Washing sodium coolant from and drying each assembly,
- Transfer of assemblies to a hot-cell facility for disassembly and repackaging, and
- Transfer of spent fuel to interim storage.

Argonne originally anticipated significant modifications to both fuel handling equipment and control systems prior to initiation of defueling. However, in order to minimize the time required to defuel, the risk of potential fuel handling equipment failure was accepted. Fuel handling equipment performed well with only routine maintenance providing an adequate safety margin during nearly continuous operation. Treatment of the EBR-II spent fuel is a state-of-the-art electrometallurgical application and will not be discussed here.

Performed in parallel to reactor defueling was the design and construction of the Sodium Process Facility. The design and construction of the Sodium Process Facility is an application of known and demonstrated technology. The conversion of alkali metal to alkali hydroxide compounds by reaction with alkali hydroxide is routinely performed around the world, e.g., DFR/PFR, at Dounreay and as planned at Superphenix.

## Phase II EBR-II Decommissioning Activities

The second decommissioning phase was sodium coolant removal and reaction. Construction of the Sodium Process Facility provided Argonne the ability to react elemental sodium with water to form sodium hydroxide, at compositions ranging from 30 to 73% by weight. All sodium treated as part of the decommissioning activities was reacted to a 73% by weight sodium hydroxide. Compositions of 70% by weight sodium hydroxide or greater are solid below 60°C. The U. S. Environmental Protection Agency, the regulatory agency for reactive and corrosive elements and compounds, does not regulate solid sodium hydroxide allowing its disposal as a low-level waste.

By late summer 2000 the secondary sodium coolant had been reacted to a solid sodium hydroxide waste and the primary sodium was being drained. Processing of the primary sodium was completed in March 2001. In addition to the sodium utilized as EBR-II coolant, 372 tonnes. Argonne also stored the Fermi I primary sodium inventory 281 tonnes, that was also reacted to sodium hydroxide and disposed of as low level waste. A total of 653 tonnes of sodium was converted to 1,450 tonnes of solid sodium hydroxide.

### Phase III Decommissioning of the EBR-II

The third and final phase of the decommissioning activity was the placement of reactor and non-reactor systems in a radiological and industrially safe condition. The planning for this phase included a detailed system-by-system evaluation to determine necessary actions based on the following definition:

Radiologically and industrially safe is the placement of equipment and facility in a condition that does not pose any unusual, unexpected or additional industrial safety risk and does not pose a radiation or contamination risk beyond normal EBR-II levels for controlled access areas.

As the system-based planning was developed, necessary or newly identified surveillance activities were identified. Surveillance provides the regulator assurance that EBR-II systems would not deteriorate.

A major component of the radiologically and industrially safe strategy was treatment of the residual radioactive sodium remaining within system piping and components. The conversion of the exposed residual sodium surfaces to a non-reactive layer of sodium carbonate was accomplished through a process called passivation. Passivation (or carbonization) is achieved through the controlled humidification of the carbon dioxide cover gas. The presence of water vapor in carbon dioxide forms a layer of sodium carbonate (sodium bicarbonate). The carbonate layer remains porous and does not impede reaction rates until a layer of greater than 20 cm has been achieved. All exposed surfaces of sodium remaining within both the primary and secondary systems have been passivated.

Subsequent to the draining of the primary sodium a close circuit TV camera was inserted into the EBR-II primary tank. Among the objectives of this visual inspection were: confirmation of completion of the sodium coolant draining process, provide a visual understanding of the draining process and residual sodium deposition locations and finally provide a visual assessment of tank and component integrity.

Visual examination provided evidence of the draining process, confirming the removal of all but very small quantities of residual sodium. An additional visual examination followed the completion of passivation of all primary systems.

#### Summary and Recommendations

Recommendations for future decommissioning activities, reactor system designs and identification of areas of potential research and development are the result of lessons learned from EBR-II decommissioning activities. Although many of the recommendations are not new, they were included due to the significance to this discussion.

Reactors plants should be shutdown in accordance to detailed planning allowing operators and regulators a common understanding of facility conditions, the processes that will take place, the interactions expected or required and to provide open communications of anticipated planning schedules.

The volume of sodium to be measured from systems should be accomplished by calculations of remaining sodium. If the potential exists for negotiation, the regulator should be educated on the relative safety, costs, risks and potential for environmental impacts from the presence of bulk or residual sodium. This activity can significantly reduce the cost to decommission a fast reactor.

A major benefit to the fast reactor community would be a reactor whose cost to decommission was “equal or near” the cost for a water-cooled reactor (PWR or BWR). Clearly, there will be significant disagreement from both within and outside of the fast reactor community. However, until a common goal is established, this or another one, and is embraced by the fast reactor community, no integrated progress will be made.

Any future fast reactor design should, as a fundamental design criteria, require all sodium systems be provided with an effective sodium removal capability, i.e., draining. In many cases techniques will be simple and inexpensive to implement. In other systems, reactor vessels or steam generators for example techniques will need to be debated.

Current methods for the reaction of residual sodium *in situ* are being studied, and applied at the EBR-II, e. g., passivation. These techniques should be seriously considered for routine application and any necessary research and development should be pursued. The formalization of specific requirements, suggested applications and process limitations should be developed.

New techniques for the removal of sodium, both bulk and residual, should be pursued for both current reactors as well as implemented into any new fast reactor designs. Techniques should address the entire range of possible alternatives, without limitations of currently existing technologies. Potential future *in situ* techniques should be identified, prioritized and fully developed allowing the decommissioning of fast reactors to be forthright and cost effective.

### Conclusion

The EBR-II decommissioning activities performed have been discussed. These activities were performed safely, effectively, efficiently and on schedule. Of primary interest are those recommendations stemming from the lessons learned in performing the decommissioning activities. Goals have been suggested for future reactor designs and current decommissioning activities. Finally, the decommissioning experience from the EBR-II has resulted in discussion of relevant Coordinated Research Program topics.

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